Effects of the Introduction of a Memory Aid on Performance in a Modified Delayed Matching to Sample Procedure

Rachel Cassidy College of Liberal Arts and Sciences, University of Florida

The present experiment explored the effects of an observing response, or "memory aid," in a delayed matching-to-sample procedure with pigeons. Trials began with the onset of a sample stimulus (one of two colors on the center key). After a delay (retention interval), two comparison stimuli were presented on side keys, only one of which matched the sample color. Responses on the matching stimulus were reinforced with food. A third (observing) key was made available when the comparison colors were shown, responses on which reproduced the sample color. This effectively converted the delayed matching-to-sample procedure to a simultaneous matching-to-sample procedure. The response requirement on this observing key increased according to a progressive-ratio schedule that began each session at its minimum of 1 response and increased in fixed increments each time the sample stimulus was reproduced. The retention interval was manipulated systematically across conditions to quantify the tradeoff between the costs of remembering and using a memory aid. Accuracy declined with increases in the retention interval. Observing responses rarely occurred spontaneously, but increased in frequency with additional training on simultaneous matching-to-sample trials. The results are discussed in relation to the training histories required to establish observing in a remembering context.

Every act of remembering involves discrete parts: A to-be-remembered stimulus is presented, and then taken away during a delay of some kind (Jans & Catania, 1980). An organism is said to remember the stimulus when its behavior is shown to be under the control of the stimulus after the delay. Thus, remembering can be characterized as a form of delayed stimulus control (Branch 1977).

There are several methods that have been successfully used to study remembering in animal research, the most common being the Delayed Matching-to-Sample (DMTS) procedure (Blough 1959). DMTS is a variation of the simultaneous matching-to-sample procedure in which a sample stimulus appears simultaneously with both an identical comparison stimulus and a comparison stimulus that differs from the sample. Responses on the comparison stimulus that matches the sample stimulus are reinforced. In a typical DMTS procedure, the comparisons are presented only after a delay (retention interval) during which neither the sample nor the comparisons are present. The task of the organism is to choose the matching comparison.

Many researchers have noted that accuracy in choosing the correct comparison stimulus decreases as the retention interval increases (Blough 1959). Increasing the retention interval also often occasions the appearance of what has been termed mediating behavior, behavior during the retention interval that is said to bridge the delay between the offset of the sample and the onset of the comparisons. These findings support the intuition that as the sample recedes farther away in time, the more cognitively effortful the act of remembering becomes. Humans, for example, are often presented with information that must be recalled at a time that is temporally distant from the present, for example, when coworkers schedule an appointment for the following week. To enhance recall, one might use memos, post-it notes, and e-mail reminders; all are examples of human mediating behavior. When remembering information for only a short period of time, however, we often do not resort to these methods because doing so would actually increase the total effort involved in the task. A good example of this is looking up a phone number and then dialing immediately, as opposed to taking the trouble to find a place to write it down. Clearly, there are tradeoffs between recall accuracy and the costs of mediating behavior.

The present research explores the effects of presenting a pigeon with the opportunity to engage in an accuracy-enhancing mediating behavior by modifying the DMTS procedure to include a memory aid. Pigeons were initially trained on a typical DMTS procedure: the pigeon was placed in a square chamber with three response keys mounted on one wall at eye level. The center key was illuminated either green or white (the sample color) and, after a delay in which all keys were dark, the two side keys were both illuminated, one green, the other white. Following initial training a modification was introduced such that at the time that the two side keys were illuminated, the center key was also illuminated red.

Responding on this center (observing) key reproduced the sample color according to a progressive-ratio (PR) schedule in which the number of responses required to reproduce the sample increased by five responses following each completed requirement. The retention interval was also increased across conditions in order to make the task more difficult. As noted before, with the increasing delay, accuracy in choosing the correct comparison color usually decreases. The introduction of the center key as a 'memory aid' or 'hint' key serves as an alternative to remembering. This memory aid, however, becomes increasingly more costly as the response requirement heightens. The objective was to better understand the tradeoffs between remembering and the use of a memory aid as the costs of each were systematically varied.

METHOD

Subjects

Four White Carneau pigeons, maintained at approximately 85% of their free-feeding weights, served as subjects. The pigeons were housed in a colony room in individual cages where they had free access to water and grit. The colony was kept on a light/dark cycle with a light duration of 16.5 hours.

Apparatus

Sessions were conducted in a standard three-key operant conditioning chamber for pigeons. The chamber contained an aluminum intelligence panel with three keys arranged horizontally. The experimental space measured 30.5 cm x 35 cm x 35 cm. Keys were arranged 23.5 cm from the floor of the chamber and were spaced 5.7 cm apart. Each key required a force of 0.12 N to register a response. Above the center key was a houselight for general illumination. Below the center key, near the floor, was a square aperture through which access to mixed grain could be obtained from a solenoid-operated hopper. All experimental events were controlled and data collected by a standard PC using MED-PC IV software.

Procedure

Initial Training. Pigeons were initially trained on a 0-s delayed matching-to sample-procedure. Trials began with the illumination of a red trial-initiation stimulus on the center key. One response on the center key changed it to either green or white. These two colors served as samples, and occurred with equal probability following a trial-initiation response. Five responses on the sample key turned off that key and illuminated the two side keys (comparisons), one green and one white. The left-right position of the comparison colors was determined randomly each trial. A response on the key whose color matched the sample was reinforced with 3-s access to mixed grain. An incorrect response was followed by a 10-s blackout in which all keys and the houselight went dark. All trials were followed by a 10-s inter-trial interval, during which the houselight rapidly flashed on and off at a rate of 0.5 s. A correction procedure was also used during initial training, wherein an incorrect response forced a repeat of the same trial configuration until the correct comparison key was pecked. Sessions were conducted daily and were terminated after either 48 reinforced trials or after 75 minutes had elapsed, whichever occurred first. Subjects were moved to the experimental phase once they had completed 5 consecutive sessions with at least 85% accuracy (correct trials/total trials). Table 1 shows the sequence and number of sessions per condition.

Experimental Phase. Following initial training, the retention interval was manipulated across conditions according to a geometric sequence (1, 2, 4, 8, and 16 s). Like initial training, 5 responses on the center sample key turned off that key and initiated the retention interval. Unlike initial training, the center ('hint') key was illuminated red simultaneously with the two side-key comparisons. Pecks on this key reproduced the sample color associated with that trial type according to a progressive ratio schedule with a step size of 5 responses and an initial response requirement of one response. That is, the ratio requirement increased by 5 responses each time the sample was reproduced. Correct responses on the comparison keys continued to be reinforced with food, irrespective of responses on the center ("hint") key. The 10-s ITI used in initial training continued, but the correction procedure was discontinued.

Each condition consisted of a minimum of 14 sessions, and continued until accuracy levels were stable. Stability criteria consisted of taking the mean of the last nine sessions of a condition and comparing the means of the first, middle, and last 3 blocks of sessions of those nine. Means of each three blocks of sessions were not to be more than 5% different than the overall mean or from each other, nor could there be evidence of a trend in the means. Table 1 lists the number of sessions per condition for each subject.

Additional training

Because behavior did not reliably contact with contingencies in place on the center 'hint' key, further training procedures were implemented.

Training Phase 1. Training Phase 1 was identical to the experimental phase described above, with the addition that, during the first 24 trials within a session, an FR 1 response requirement replaced the PR schedule on the center 'hint' key. Completing this FR 1 requirement changed the center key from red to the sample color associated with that trial configuration. Prior to the completion of this requirement, pecks to the comparison keys received no consequences. The requirement was lifted after the first 24 trials, and the remaining trials

Table 1. Sequence of conditions and number of sessions per condition for each subject.

Condition	Subject		
	009	096	289
0s Retention Interval	35	35	35
1s Retention Interval	30	15	34
2s Retention Interval	23	22	17
4s Retention Interval	19	18	24
8s Retention Interval	14	28	31
16s Retention Interval	N/A	N/A	16
Training Phase 1	28	19	N/A
8s Retention Interval (2)	N/A	16	N/A
Training Phase 2	67	39	64
8s Retention Interval (3)	N/A	19	N/A

in the session were identical to the experimental phase. Because this procedure was insufficient to boost accuracy, an additional training phase was introduced.

Training Phase 2. Training Phase 2 was identical to Training Phase 1, with the addition of a correction procedure in place during the first 24 trials in which an FR 1 response requirement was in place on the center 'hint' key. Incorrect responses on any of these first 24 trials forced a repeat of the same trial configuration.

RESULTS

Figure 1 shows overall accuracy (% correct) and accuracy by trial type as a function of retention interval for each pigeon. Accuracy decreased as retention interval increased, with the most dramatic decreases occurring at retention intervals beyond 4 s. The accuracy for each trial type is also tracked in order to provide information on the determinants of accuracy decrements. Trial types 1 and 2 both had a green sample, with a left and right comparison color, respectively; trial types 3 and 4 had a white sample with left and right the comparison color, respectively. For Pigeon 096 in the 8-s retention interval condition, the high accuracy on trial types 1 and 3 with an overall accuracy of 50% indicates that the pigeon was choosing the left comparison key regardless of the sample color. Because the trial types were chosen randomly, there is a 0.5 probability that the correct comparison color would appear on the left, resulting in the overall accuracy of 50%. Pigeon 289 showed a similar pattern in choosing the right key during the 16-s retention-interval condition.

The experimental phase did not consist of forced exposure to the contingency associated with the 'hint' key, though during the pre-training experimental conditions each pigeon did contact the hint key on several occasions. The initial response requirement was FR 1 and each subject reproduced the sample a number of times across conditions, with at least one pigeon (289) having a steady break point on the center key PR schedule. No pigeon reliably reproduced the sample more than once per session, however; that is, they did not complete the next-highest ratio of 6 after the initial response requirement was met. This pattern continued despite a decrease in accuracy at higher retention-interval values. To ensure contact with the contingency, Training Phase 1 was initiated, which required pigeons to reproduce the sample on an FR 1 schedule during the first 24 trials of each session before pecks to the comparison keys could receive consequences. The pigeons were not reliably more accurate, however, on those trials during which the sample had been reproduced.

The low accuracy when using the observing key was perhaps due to the fact that the pigeons had never been exposed to a simultaneous match-to-sample procedure. Training Phase 2 was therefore initiated to train simultaneous matching-to-sample performance. This phase consisted of the addition of a correction procedure in which a peck to an incorrect comparison key on any given trial caused a repeat of that trial type until the correct comparison key was chosen. The reproduction of the sample transforms the trial into a simultaneous matching-to-sample trial (the sample appears simultaneously with the comparisons). During both training phases, the response requirement on the center 'hint' key remained at FR 1 during the remaining trials in order to facilitate use of the 'hint' key.

Figure 2 shows the effects of training on accuracy on only the trials in which the sample had been reproduced on the center key. Pigeons 009 and 096 were exposed to

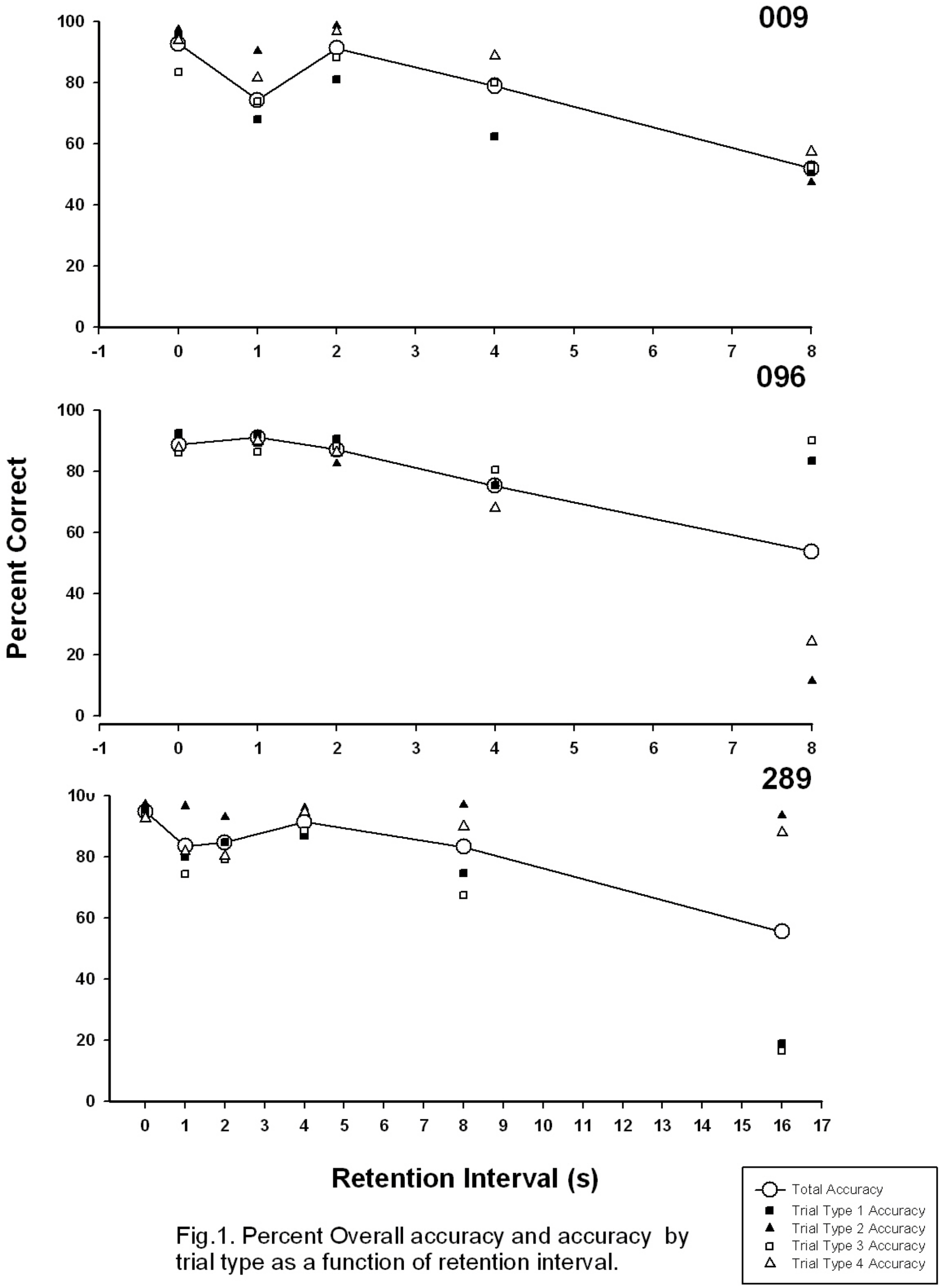

Fig.1. Percent Overall accuracy and accuracy by trial type as a function of retention interval.

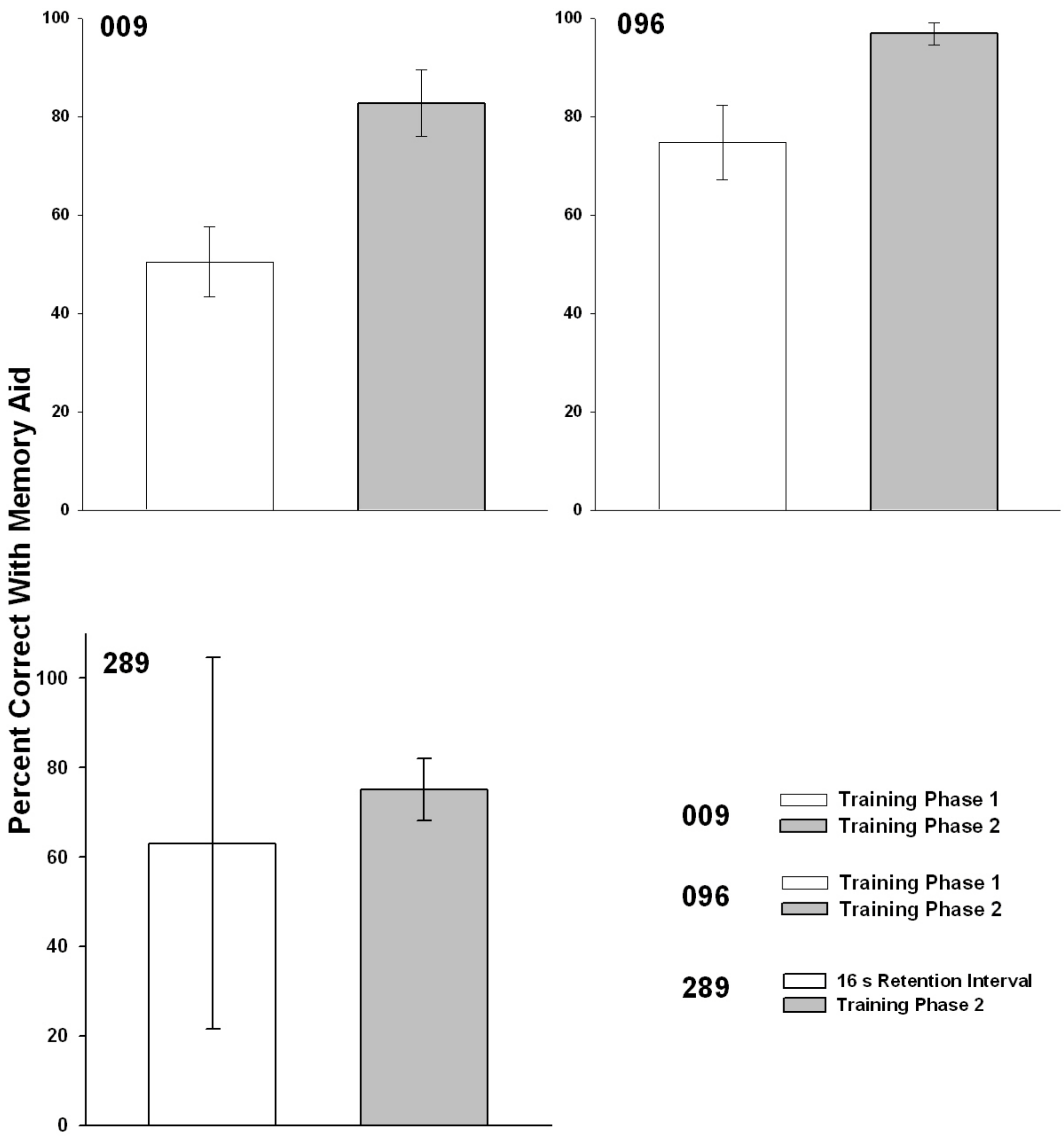

Figure 2. Percent correct on trials when the sample has been reproduced. Error bars represent one standard deviation above and below the mean.

both Training Phase 1 and Training Phase 2. For these two subjects the effect of Training Phase 2 is apparent in the large increase in accuracy when using the observing key. In contrast to the other subjects, Pigeon 289 did not receive Training Phase 1, so the effects of Training Phase 2 are compared to the 16-s retention interval condition, which occurred immediately prior to Training Phase 2. Accuracy when the sample had been reproduced increased after Training Phase 2.

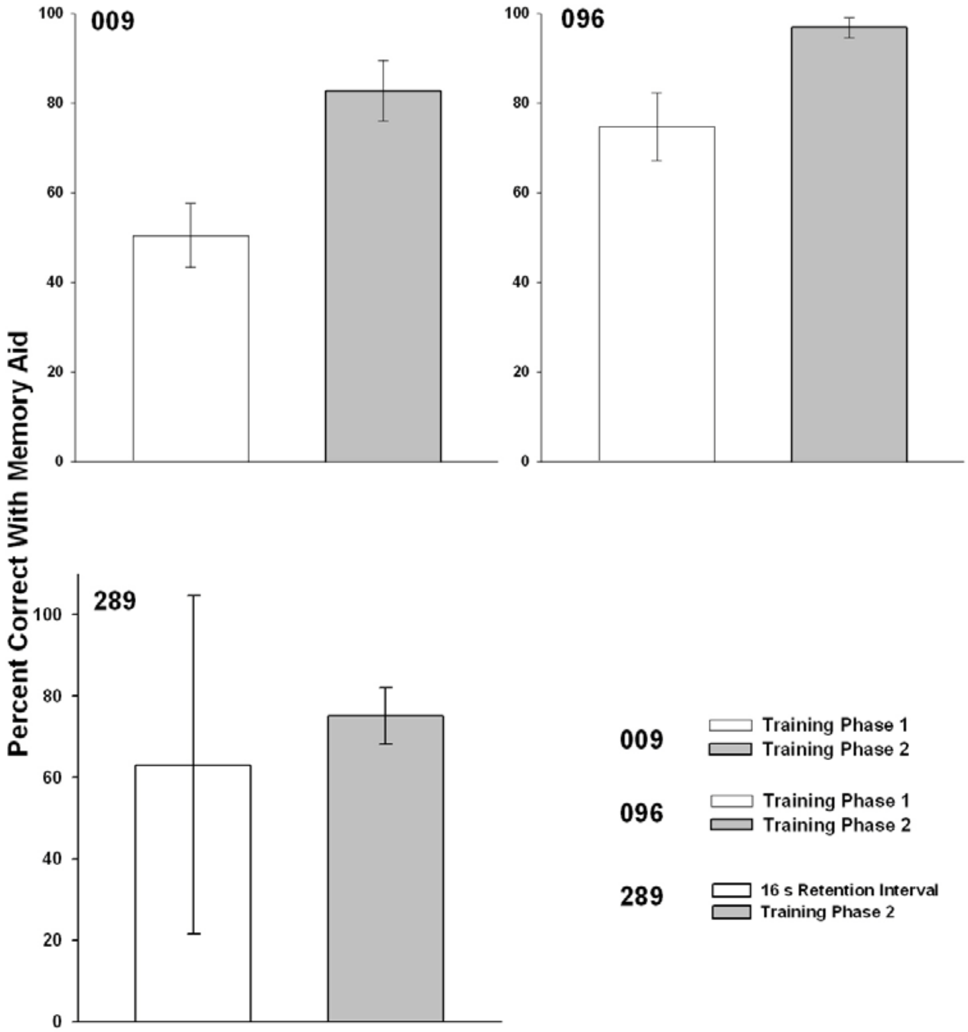

Figure 2. Percent correct on trials when the sample has been reproduced. Error bars represent one standard deviation above and below the mean.

DISCUSSION

The effect of the introduction of a memory aid in this modification of a DMTS procedure is difficult to assess given that the observing key was not consistently pecked prior to training. Although overall accuracy decreased as a function of retention interval length, the pigeons did not spontaneously reproduce the sample. Training phases initiated later in the experiment arranged the first half of each session such that pigeons were forced to reproduce the sample on an FR 1 schedule before pecks to either of the comparisons could receive consequences. The lack of improved accuracy on those trials during which the sample had been reproduced provides evidence that the memory aid key was not actually functioning as a memory aid in human terms; that is, the reproduction of the same sample color evidently failed to 'remind' the subjects of the sample.

The performance seen under this modification of the DMTS procedure raises important issues regarding stimulus control by the sample in DMTS procedures, as well as what subjects are remembering when accuracy levels are high. In a functional analysis of DMTS findings, Wixted (1989) hypothesized that the efficacy of the sample as a discriminative stimulus is related to its ability to function as a conditioned reinforcer. In the context of DMTS procedures, Wixted modified the delay-reduction hypothesis—which indicates that conditioned reinforcers gain efficacy through their correlation with a reduction in the delay to the availability of reinforcement—to include the effects of the retention interval. This model predicts that when the retention interval is large or the delay reduction associated with the sample is small, the sample stimulus will exert little control as a discriminative stimulus. He postulated that in such a context the comparison stimuli will function as discriminative stimuli independently of the sample. This is an important consideration for interpreting the results of the present study.

Consistent with the stipulations of Wixted's model that would predict the independence of the comparison stimuli as discriminative stimuli, the onset of the sample in the present experiment does not correlate with a meaningful reduction in the delay until reinforcement is available. Additionally, when the retention interval was large, biases developed for two pigeons (096 and 289) which began to respond at chance levels. When taking the comparison stimuli as independent of the sample, however, then each key has an equal probability of reinforcement, so the subject still earns an average of 50% of the available reinforcement through chance responding. More importantly, the pigeons did not reliably use the observing (memory aid) key without explicit training, though effective use could have ensured 100% of the available reinforcement.

When the pigeons were exposed to Training Phase 1 in which they were forced to reproduce the sample before they could peck either of the comparison keys, their accuracy on the trials in which the sample was reproduced was low (Figure 2). This indicates that the memory aid key was not actually functioning as a memory aid in human terms. The explanation for this discrepancy may lie in the way that DMTS trials are learned. When the retention interval is short, and the sample presumably retains its discriminative function, it is unlikely that the pigeons were matching the color green with the color green; in other words, both the sample and the configuration of the comparisons as they appear after the sample are learned as discrete events. The differential accuracies by trial configuration (Figure 1) support this conclusion. When there is a short retention interval, one would predict that the pigeons would be unlikely to make use of a memory aid, which indeed they did not. As the retention interval increased, however, and remembering the trial configuration presumably became more difficult, then the introduction of a third key light simultaneously with the comparisons might be expected to disrupt rather than to enhance performance.

If the diminished stimulus control by the sample during longer retention-interval conditions, supported by chance responding, is evidence that the pigeons no longer remembered the sample, then it is unlikely that a memory aid that reproduces the sample color later on in the trial would simply 'remind' the pigeons of the sample in the absence of explicit pairing of the two stimuli. The subsequent training phases that improved accuracy when using the memory aid suggests that, with proper pairing, pigeons can utilize the memory aid key in a fashion analogous to the manner in which humans use memory aids.

In conclusion, the results of the present experiment provide evidence that the mere opportunity to reproduce the sample color did not function as a memory aid without explicit training. Future experiments using this procedure should begin with simultaneous match-to-sample training to facilitate performance during trials when the sample has been reproduced and appears simultaneously with the comparisons. Additionally, future experimentation using this procedure should include explicit training of the observing response, preferably with a correction procedure in place to ensure sufficient pairings of the original and reproduced sample colors. Such experimentation is currently underway.

REFERENCES

Berryman, R, Cumming, W.W., & Nevin, J.A. (1963). Acquisition of delayed matching in the pigeon. *Journal of the Experimental Analysis of Behavior, 6,* 101-107.

Blough, D.S. (1959). Delayed Matching in the Pigeon. *Journal of the Experimental Analysis of Behavior, 2,* 151-160.

Branch, M.N. (1977). On the role of 'memory' in the analysis of behavior. *Journal of the Experimental Analysis of Behavior, 28,* 171-179.

Cumming, W.W. & Berryman, R. (1965). The complex discriminated operant: Studies of matching-to-sample and related problems. In D.D. Mostofsty (Ed.) *Stimulus Generalization* (pp. 284-330). Stanford, CA: Stanford University Press.

Dinsmoor, J.A. (1985). The role of observing and attention in establishing stimulus control. *Journal of the Experimental Analysis of Behavior,43,* 365-381.

Jans, J.E., and Catania A.C. (1980). Short-term remembering of discriminative stimuli in pigeons. *Journal of the Experimental Analysis of Behavior, 34,* 17-183.

Mackay, H.A. (1991). Conditional stimulus control. In Iverson, I.H. & Lattal, K.A. (Eds.) *Experimental Analysis of Behavior, Part 1* (pp. 301-350). New York: Elsevier.

Nevin, J.A., Davison, M., & Shahan, T.A. (2005). A theory of attending and reinforcement in conditional discriminations. *Journal of the Experimental Analysis of Behavior, 84,* 281-303.

Reynolds, G.S. Attention in the Pigeon. *Journal of the Experimental Analysis of Behavior, 4,* 203-208.

Shimp, C.P. & Moffitt, M. (1974). Short-term memory in the pigeon: Stimulus-response associations. *Journal of the Experimental Analysis of Behavior, 22,* 507-512.

Shimp, C.P.(1976). Short-term memory in the pigeon: Relative recency. *Journal of the Experimental Analysis of Behavior, 25,* 55-61.

Stafford, D. & Branch, M.N. (1998). Effects of step size and break-point criterion on progressive-ratio performance. *Journal of the Experimental Analysis of Behavior, 70,* 123-138.

White, K. G. (1985). Characteristics of forgetting functions in delayed matching to sample. *Journal of the Experimental Analysis of Behavior, 44,* 15–34

Wixted, J.T., 1989. Nonhuman short-term memory: a quantitative reanalysis of selected findings. *Journal of the Experimental Analysis of Behavior, 52,* 409–426.